1   1.   A pipeline inspection system comprising,

2   a wave launcher in communication with a pipeline and adapted to transmit an

3   input waveform having a selected input energy along a longitudinal axis of said pipeline,

4   and to receive a reflected component of said input waveform from said pipeline, said

5   reflected component having a characteristic reflected energy,

6   an analyzer in communication with said wave launcher and adapted to generate

7   said input waveform, and to receive said reflected component of said input waveform

8   from said wave launcher, and

9   a processor in communication with said analyzer and adapted to compare said

10   input waveform with said reflected component of said input waveform to determine a

11   characteristic of said pipeline.

1   2.   The apparatus of claim 1, wherein said processor is further adapted to compare

2   said input waveform with said reflected component to detect an anomaly in said pipeline.

1   3.   The apparatus of claim 2, wherein said anomaly is at least one of a crack, a

2   corrosion, a leak, a location of an end wall, an obstruction, a flange, a weld, and a

3   restriction in said pipeline.

1   4.   The apparatus of claim 2, wherein said processor is further adapted to compare

2   said input waveform with said reflected component to determine a location of said

3   anomaly in said pipeline.

1   5.   The apparatus of claim 2, wherein said processor is further adapted to compare

2   said input waveform with said reflected component to determine a shape of said anomaly

3   in said pipeline.

1   6.   The apparatus of claim 2, wherein said processor is further adapted to compare

2   said input waveform with said reflected component to determine one of an absolute size

3   of said anomaly and a relative size of said anomaly relative to an internal diameter of said

4   pipeline.

1   7.   The apparatus of claim 1, wherein said processor is further adapted to compare

2   said input waveform with said reflected component to determine an axial curvature in

3   said pipeline.

1 8. The apparatus of claim 1, wherein said processor is further adapted to compare

2 said input waveform with said reflected component to determine location points along

3 said pipeline relative to an initial known location.

1 9. The apparatus of claim 1, wherein said wave launcher further comprises a probe

2 antenna, said probe antenna adapted for transmitting said input waveform into said

3 pipeline.

1 10. The apparatus of claim 9, wherein said probe antenna of said wave launcher is in

2 physical contact with said pipeline.

1 11. The apparatus of claim 1, wherein said analyzer is further adapted to detect said

2 reflected component along said longitudinal axis of said pipeline.

1 12. The apparatus of claim 1, wherein said processor is further adapted to generate a

2 mathematical model representative of said pipeline.

1 13. The apparatus of claim 12, wherein said mathematical model is ideal.

1 14. The apparatus of claim 12, wherein said mathematical model is lossy.

1 15. The apparatus of claim 12, wherein said mathematical model is one of an

2 averaging model and a cross-sectional model.

1 16. The apparatus of claim 12, wherein said processor is further adapted to generate a

2 model transfer function relating a model input waveform to a model reflected component,

3 an actual transfer function relating an actual input waveform to an actual reflected

4 component, and to determine said characteristic at least in part by comparing said model

5 transfer function with said actual transfer function.

1 17. The apparatus of claim 12, wherein said processor is further adapted to determine

2 said characteristic of said pipeline at least in part by comparing an actual reflected

3 component with a model reflected component.

1 18 The apparatus of claim 1, wherein said analyzer is further adapted to extract a

2 characteristic energy and phase for said input waveform and said reflected component.

1 19. The apparatus of claim 1, wherein said analyzer is further adapted to generate said

2 input waveform with a frequency above a characteristic cutoff frequency of said pipeline.

1 20. The apparatus of claim 1, wherein said analyzer is further adapted to generate said

2 input waveform at a frequency within a range of frequencies for which a dominant mode

3 for said pipeline exists.

1   21.   The apparatus of claim 20, wherein said input waveform comprises a plurality of

2   input signals within said range of frequencies.

1   22.   The apparatus of claim 21, wherein said analyzer is further adapted to detect

2   differences in velocity between said plurality of input signals as said input signals

3   propagate in said pipeline, and said processor is further adapted to determine a curvature

4   of said pipe along said longitudinal axis from said differences in velocity.

1   23.   The apparatus of claim 21, wherein said analyzer is further adapted to detect

2   differences in velocity between reflected components of each of said plurality of input

3   signals to determine a curvature of said pipeline along said longitudinal axis.

1   24.   The apparatus of claim 1, wherein said analyzer is further adapted to generate an

2   electromagnetic waveform as said input waveform.

1   25.   The apparatus of claim 1, wherein said analyzer is further adapted to generate an

2   acoustic waveform as said input waveform.

1   26.   The apparatus of claim 1, wherein said analyzer is further adapted to generate said

2   input waveform as one of a spread spectrum waveform, a chirp waveform, and a soliton

3   waveform.

1   27.   The apparatus of claim 1, wherein said analyzer is further adapted to generate said

2   input waveform as a wideband waveform.

1   28.   The apparatus of claim 1 further comprising calibration elements adapted to

2   temperature stabilize said analyzer.

1   29.   A method of inspecting a characteristic of a pipeline, said method comprising,

2   transmitting an input waveform having a selected input energy along a

3   longitudinal axis of said pipeline,

4   receiving a reflected component of said input waveform from said pipeline, said

5   reflected component having a characteristic reflected energy, and

6   comparing said input waveform with said reflected component of said input

7   waveform to determine said characteristic of said pipeline.

1   30.   The method of claim 29 further comprising, comparing said input waveform with

2   said reflected component to detect an anomaly in said pipeline.

1 31.   The method of claim 30, wherein said anomaly is at least one of a crack, a

2 corrosion, a leak, a location of an end wall, an obstruction, a flange, a weld, and a

3 restriction in said pipeline.

1 32.   The method of claim 30 further comprising, comparing said input waveform with

2 said reflected component to determine a location of said anomaly in said pipeline.

1 33.   The method of claim 30 further comprising, comparing said input waveform with

2 said reflected component to determine a shape of said anomaly in said pipeline.

1 34.   The method of claim 30 further comprising, comparing said input waveform with

2 said reflected component to determine one of an absolute size of said anomaly and a

3 relative size of said anomaly relative to an internal diameter of said pipeline.

1 35.   The method of claim 29 further comprising, comparing said input waveform with

2 said reflected component to determine an axial curvature in said pipeline.

1 36.   The method of claim 29 further comprising, comparing said input waveform with

2 said reflected component to determine location points along said pipeline relative to an

3 initial known location.

1 37.   The method of claim 29, further comprising, detecting said reflected component

2 along said longitudinal axis of said pipeline.

1 38.   The method of claim 29 further comprising, generating a mathematical model

2 representative of said pipeline.

1 39.   The method of claim 38, wherein said mathematical model is ideal.

1 40.   The method of claim 38, wherein said mathematical model is lossy.

1 41.   The method of claim 38, wherein said mathematical model is one of an averaging

2 model and a cross-sectional model.

1 42.   The method of claim 38 further comprising, generating a model transfer function

2 relating a model input waveform to a model reflected component, an actual transfer

3 function relating an actual input waveform to an actual reflected component, and to

4 determine said characteristic at least in part by comparing said model transfer function

5 with said actual transfer function.

1 43.   The method of claim 38 further comprising, determining said characteristic of

2 said pipeline at least in part by comparing an actual reflected component with a model

3 reflected component.

1 44   The method of claim 29 further comprising, extracting a characteristic energy and
2 phase for said input waveform and said reflected component.

1 45.   The method of claim 29 further comprising, generating said input waveform with
2 a frequency above a characteristic cutoff frequency of said pipeline.

1 46.   The method of claim 29 further comprising, generating said input waveform at a
2 frequency within a range of frequencies for which a dominant mode for said pipeline
3 exists.

1 47.   The method of claim 46, wherein said input waveform comprises a plurality of
2 input signals within said range of frequencies.

1 48.   The method of claim 47 further comprising, detecting differences in velocity
2 between said plurality of input signals as said input signals propagate in said pipeline,
3 and determining a curvature of said pipe along said longitudinal axis from said
4 differences in velocity.

1 49.   The method of claim 47 further comprising, detecting differences in velocity
2 between reflected components of each of said plurality of input signals to determine a
3 curvature of said pipeline along said longitudinal axis.

1 50.   The method of 29 further comprising, generating an electromagnetic waveform as
2 said input waveform.

1 51.   The method of claim 29 further comprising, generating an acoustic waveform as
2 said input waveform.

1 52.   The method of claim 29 further comprising, generating said input waveform as
2 one of a spread spectrum waveform, a chirp waveform, and a soliton waveform.

1 53.   The method of claim 29 further comprising, generating said input waveform as a
2 wideband waveform.

1 54.   The method of claim 29 further comprising, calibrating said analyzer to be
2 temperature stable.

1 55.   A method of determining a location of a point along a pipeline, said method
   comprising,
3   transmitting an input waveform having a selected input energy along a
4 longitudinal axis of said pipeline,

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5   receiving a reflected component of said input waveform from said pipeline, said

6   reflected component having a characteristic reflected energy, and

7   comparing said input waveform with said reflected component of said input

8   waveform to determine said location of said point along said pipeline.

1   56.   A method of inspecting a characteristic of a pipeline, said method comprising,

2   transmitting an input waveform having a selected input energy along a

3   longitudinal axis of said pipeline,

4   receiving a reflected component of said input waveform from said pipeline, said

5   reflected component having a characteristic reflected energy, and

6   determining said characteristic of said pipeline using an error estimate, said error

7   estimate depending on a known point along said pipeline relative to said characteristic.

1   57.   The method of claim 56 wherein said error estimate further depends on one of a

2   conductance, a radius, and a cross-sectional shape of said pipeline.

1   58.   A method of inspecting a characteristic of a pipeline, said method comprising,

2   generating an input waveform,

3   launching said input waveform into said pipeline,

4   receiving from said pipeline a reflected component having a characteristic

5   reflected energy of said input waveform,

6   calculating a mathematical function of said characteristic reflected energy from

7   said reflected component of said input waveform,

8   determining a model mathematical function of model reflected energy from a

9   model component of a model input waveform, and

10 determining said characteristic of said pipeline by comparing said mathematical

11 function of said reflected energy to said model mathematical function of said model

12 reflected energy.